Gender Variation in Creaky Voice and Fundamental Frequency

Honors Research Thesis

Presented in partial fulfillment of the requirements for graduation with honors research distinction in Linguistics in the undergraduate colleges of The Ohio State University

by

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April 2015

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Abstract

The current study examines creaky voice and the fundamental frequency associated with modal and creaky voicing across genders. I analyzed read speech data from five male and five female Midwestern Americans between the ages of 18 and 25. I found that female speakers use creaky voice more often than male speakers in this dialect. Additionally, the male speakers produced a much smaller difference in fundamental frequency between modal and creaky voicing than the female speakers. I suggest that the difference in fundamental frequency ranges across genders may cause creaky voice to be more perceptually salient in the speech of women than men. As a result, I propose that women use creaky voice more often than men because it is more salient in their speech and may thus more easily carry social meaning.

1. Introduction

Creaky voice is a mode of voicing characterized by aperiodicity and a drop in fundamental frequency (F0) (Gordon & Ladefoged, 2001; Ladefoged & Maddieson, 1996). It has also been called creak, vocal fry, glottalization, laryngealization, pulse register phonation (Gerratt & Kreiman, 2001), as well as irregular vibration (Hanson *et al*., 2001). Some languages, such as Jalapa Mazatec and Kashaya Pomo, employ creaky voice to create phonemic contrasts (Gordon & Ladefoged, 2001). In English, however, creaky voice has been observed as both a sociophonetic marker (Henton & Bladon, 1988) and a prosodic marker (Dilley *et al*., 1996; Redi & Shattuck-Hufnagel, 2001).

Creaky voice has previously been found to be a characteristic of masculine speech. In a study of two dialects of British English, experimenters found that creaky voice was more often used by male participants than by female participants, and thus proposed that creaky voice is more likely to be associated with the speech of men than the speech of women (Henton & Bladon, 1988). In contrast, in a more recent study of young American women, experimenters found that creaky voice is also a characteristic of feminine speech (Wolk *et al*., 2012). Because Wolk *et al*. (2012) only examined the speech of women, however, more research is necessary to determine the relationship between gender and creaky voice in American English. One such study examining the connection between creaky voice and gender was conducted by Yuasa (2010), who observed that female speakers of Californian English produce creaky voice more frequently than their male counterparts. Yuasa (2010) also found that creaky voice was perceived as educated and professional, and suggested that women use creaky voice to project that particular social image. In the current study, I find additional evidence that women use creaky

voice more frequently than men in a comparison of the frequency of creaky voicing in male and female Midwestern American English speech.

Previous work also indicates that creaky voice is more likely to be used in particular prosodic environments. According to Henton and Bladon (1988), creaky voice is often found at the ends of utterances. Additionally, in Dilley *et al.*'s (1996) study examining the effects of prosody on the use of creaky voice when producing vowel-initial words, the authors observed that speakers were more likely to use creaky voice when producing word-initial vowels at the beginning of an intonational phrase, and when producing word-initial vowels that are pitch-accented. Similarly, Redi and Shattuck-Hufnagel (2001) found supporting evidence for the findings from Dilley *et al*. (1996), and further observed that utterance-final intonational phrase boundaries are more likely to be produced using creaky voice than utterance-medial intonational phrase boundaries. Additional results from Redi and Shattuck-Hufnagel (2001) indicate that utterance-medial full intonational phrases are more likely to be produced with creaky voice than utterance-medial intermediate intonational phrases. In my study, I have minimally controlled for the effects of prosody on the production of creaky voice by using read productions of the same five paragraphs for each speaker.

In the current study, I also examined the relationship between gender and speakers' fundamental frequencies for both modal and creaky voicing. Previously, in a study examining the ranges in fundamental frequency employed by men and women across multiple phonation registers, Hollien and Michel (1968) found that women have a wider and higher range in fundamental frequency during modal voicing than men, but that both genders have a very similar range in fundamental frequency during creaky voicing. These results suggest that the difference in fundamental frequency between modal and creaky voicing is larger for women than for men.

However, in their study, participants were asked to imitate frequencies that were presented to them as pure tones and from these data, Hollien and Michel (1968) described the possible ranges in fundamental frequency that can be produced by men and women in both modal and creaky voicing. Because their study examined the imitation of tones rather than natural speech, the frequency ranges they observed may not be representative of normal speech production. Additionally, their study aimed to find the modes of voicing corresponding to specific frequencies, rather than the frequencies corresponding to identifiable modes of voicing, as my study does.

Hillenbrand and Houde (1996) found that the most significant perceptual cue for creaky voice is the lowering of F0. I hypothesize that, if there is a greater difference in F0 between modal and creaky voicing for women than men as suggested by Hollien and Michel (1968), the usage of creaky voice is more perceptually salient in the productions of women than men, leading women to produce creaky voice more frequently than men. Thus, in my study I examined the F0 differences for men and women between modal and creaky voicing to draw connections between the F0s associated with each mode of voicing for each gender and the social meanings associated with the frequency with which male and female speakers employ creaky voicing (Yuasa, 2010).

2. Methods

2.1 Corpus

The speech data used in this study came from a corpus of read passages collected by Burdin *et al.* (2014). The corpus contains 30 passages, each read by 15 male and 15 female college students. Each participant is a self-reported monolingual speaker of American English

with no reported history of a speech or hearing impairment. Each speaker produced each passage twice, first in plain speech and then in careful speech. For each speaking style, the paragraphs were presented one at a time in random order. The recordings of each passage are all approximately 60 seconds in duration. The passages were recorded in a sound-attenuated booth using high-quality digital recording equipment. For this study, I examined speech production in five of the passages from the corpus, read by five female and five male speakers of the Midland dialect using plain speech (for a total of 50 recorded paragraphs). The texts of the passages used in this study can be found in the appendix.

2.2 Voice Quality Analysis

Using Praat, each syllable nucleus in the recordings was labeled by hand as creaky, modal, neither creaky nor modal (i.e., another voice quality), deleted, or disfluent. I identified creaky voicing as speech with a audibly lower F0 and visibly aperiodic waveform. Non-creaky, non-modal voice quality was identified as speech with otherwise atypical quality but without the characteristics of creaky voice. Deleted nuclei were identified as nuclei which had become devoiced or otherwise unarticulated during production. Speech marked as disfluent included utterances during which the speaker coughed, laughed, mispronounced words, or did not read the passage accurately.

If multiple modes of voicing were used for a single syllable nucleus, each mode of voicing was segmented and labelled appropriately, as illustrated in Figure 1. In Figure 1, the waveform of the utterance is accompanied by three tiers of annotation: the words that were produced in standard orthography, the vowels in a plain-text phonetic transcription including stress, and the voice quality labels that I assigned to each vowel. The label “m” codes for modal voicing, while the label “c” codes for creaky voicing. Figure 1 illustrates a series of syllable

nuclei with more than one mode of voicing. In the second syllable of "idea," the vowel is mostly modal with a small portion of creaky voice at the end. The following vowel in "is" begins with creaky voicing, but becomes modal for the ending portion. The vowel in "that" is similar to the final vowel in "idea": it is mostly modal with a small portion of creaky voice at the end before a final glottal stop.

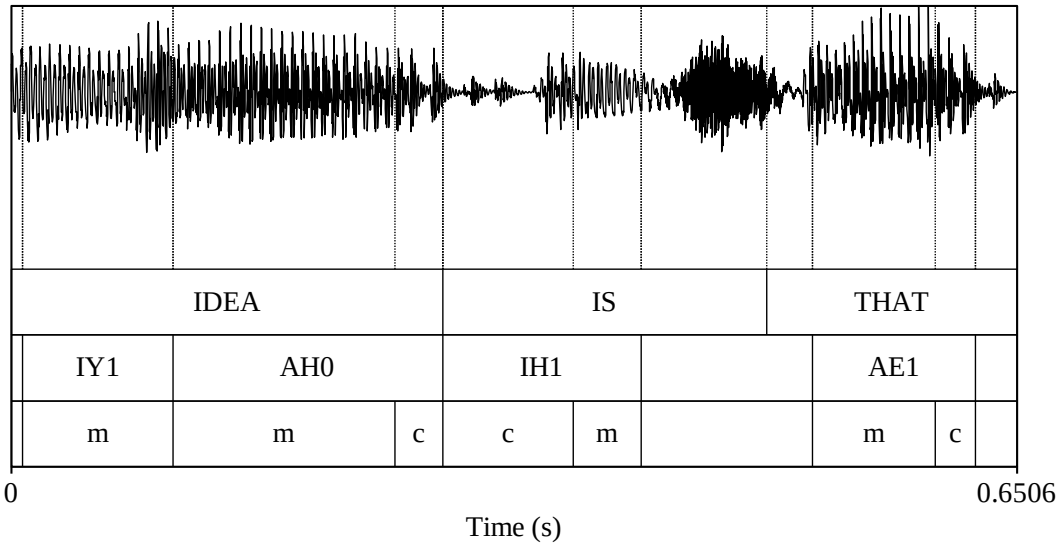

Figure 1: Example of a series of syllables labeled with more than one mode of voicing. Modal voicing is indicated by "m" and creaky voicing is indicated by "c" in the third annotation tier.

For the 13,932 syllable nuclei, the label(s), mean F0 for each labeled segment, start time, and end time were extracted. I excluded 339 syllables that were labeled neither creaky nor modal, or partially neither creaky nor modal; 455 syllables that were labeled as deleted; and 345 syllables that were labeled as disfluent. The analysis is therefore based on syllables that were fully modal, fully creaky, or a combination of modal and creaky voiced. A total of 12,793 syllable nuclei were included in my final analysis, with 1,237-1,320 syllables per speaker.

Figure 2 shows productions of the word "greed" in modal and creaky voice for one of the female speakers. The vowel in the top panel is evidently modal, with a periodic waveform. In

contrast, the bottom waveform illustrates creaky voicing, with the vowel characterized by several distinct glottal pulses.

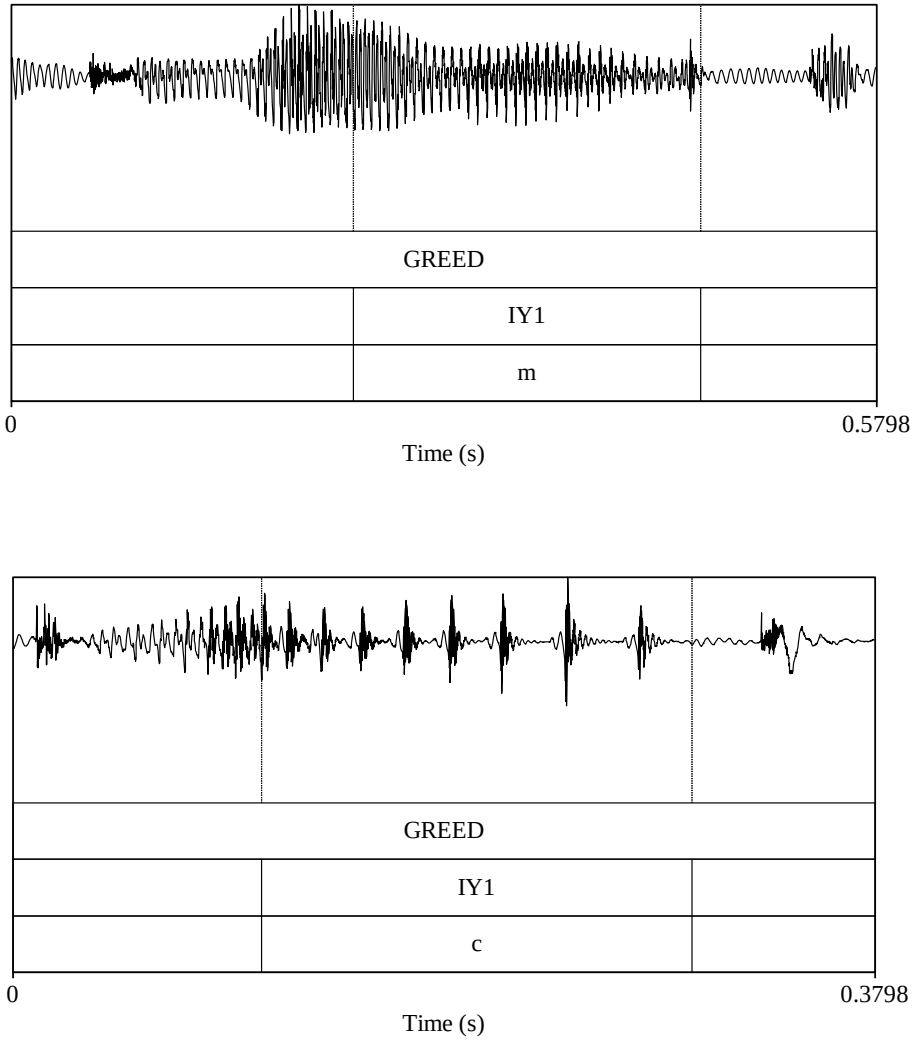

Figure 2: Productions of "greed" with modal voicing (top) and creaky voicing (bottom) by the same female speaker.

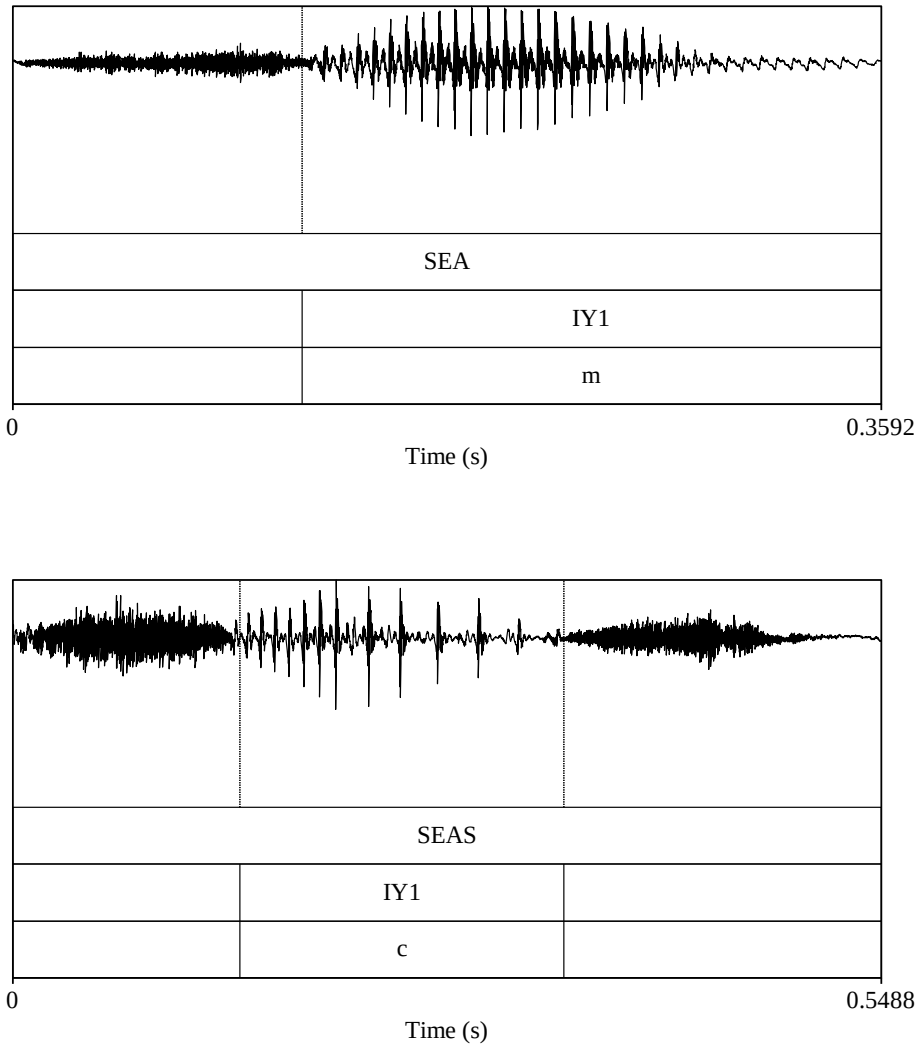

Figure 3: Productions of "sea" and "seas" in modal voicing (top) and creaky voicing (bottom) by the same male speaker.

Similarly, modal and creaky productions by one of the male speakers are shown in Figure 3. In the top panel, the waveform illustrates a modal production of the word "sea." In contrast, the bottom panel shows the word "seas" produced by the same male speaker with creaky voicing. As in the comparison shown in Figure 2, the creaky production exhibits fewer, more distinct glottal pulses than the modal production, consistent with the lower F0 and aperiodicity characteristic of creaky voice.

2.3 Reliability

In order to assess how consistently I labeled the voice quality of the syllable nuclei, I re-labeled the nuclei in one of the recordings of each of the five texts used in my study. The paragraphs I selected for my reliability assessment were read by five different speakers; three of those were read by women and two by men. I calculated the percent agreement between my original and repeated labels. I found that I labeled 87.83% of the nuclei with the same voice quality across the two transcriptions, confirming that I was fairly consistent in my judgments of voice quality. My analysis was based on the original labels I assigned to each syllable nucleus.

3. Results

To explore the effect of gender on the overall rate of creaky voicing, I calculated the proportion of syllables containing creaky voice out of the total number of modal and creaky syllables produced by each speaker. Syllables with periods of both modal and creaky voice were treated as creaky syllables in this analysis. Of all the syllables included in my analysis, around 15% were partially or entirely creaky. Figure 1 shows the mean proportion of syllables containing creaky voice for each gender. As shown in Table 1, the female speakers produced a higher proportion of syllables with creaky voice than the male speakers. About 18% of syllables produced by the female speakers were partially or entirely creaky; in contrast, about 12% of the syllables produced by the male speakers were partially or entirely creaky. To confirm this interpretation of the data, I conducted a two-sample t-test comparing the proportion of syllables containing creaky voice across gender. I found that gender has a marginally significant effect on the proportion of syllables containing creaky voice ($t(8) = 2.04$, $p = 0.076$), suggesting that the women in my sample used creaky voicing somewhat more often than the men.

Gender	Proportion of creaky syllables
Male	0.124 (0.045)
Female	0.183 (0.046)

Table 1: Mean proportion of syllables containing creaky voice for male and female speakers. Standard deviations are shown in parentheses.

To explore the effect of gender on the implementation of creaky voice within the syllable, I examined the subset of syllables for each speaker that contained creaky voicing, including those syllables that had more than one mode of voicing within a single nucleus as well as those that were entirely creaked (see Figure 1). For each syllable containing creaky voicing, I calculated the total duration of creaky voicing within the syllable and compared that measure to the total duration of the syllable to obtain a measure of the proportion of creaky voicing within the syllable. The mean proportion of creaky voicing within syllables for each gender is shown in Table 2. For both genders, syllables containing creaky voice were creaked for about 90% of their duration, indicating that the syllables containing creak for both genders were usually almost categorically creaky. A two-sample t-test comparing the proportion of creaky voice within the syllable across gender confirmed that there is no significant difference in the proportion of creaky voice within creaky syllables across men and women ($t(8) = -0.078$, $p = 0.94$). Thus, in my sample the implementation of creaky voice did not differ across genders.

Gender	Proportion of creaky voice within syllables
Male	0.907 (0.068)
Female	0.904 (0.065)

Table 2: Mean proportion of creaky voice within syllables for male and female speakers. Standard deviations are shown in parentheses.

Finally, I examined the fundamental frequency difference between modal and creaky voicing for each gender. For each speaker I calculated the mean fundamental frequency during modal voicing, as well as the mean fundamental frequency during creaky voicing. I then subtracted the mean creaky F0 from the mean modal F0 to find the mean difference in F0 between the two modes of voicing for each speaker. Across all speakers, the average difference between modal F0 and creaky F0 is 63.30 Hz. Table 3 shows the mean difference in F0 between the two voice qualities for male and female speakers, as well as the mean creaky F0 and mean modal F0 for each gender. As shown in Table 3, there is a greater difference in F0 between the modes for the female speakers than for the male speakers. The average difference in F0 between the modes of voicing for the female speakers is well above the mean, at almost 90 Hz. In contrast, the average difference in F0 between the modes of voicing for the male speakers is well below the mean, at about 37 Hz. This difference was confirmed by a two-sample t-test, which revealed a significant difference in F0 between creaky and modal voicing for men and women ($t(8) = 7.58$, $p < 0.001$).

Gender	Mean modal F0	Mean creaky F0	F0 Difference (Hz)
Male	122.06 (16.89)	85.26 (9.52)	36.80 (13.93)
Female	209.44 (5.16)	119.64 (9.15)	89.80 (7.11)

Table 3: Mean modal and mean creaky F0s for male and female speakers, and the difference in F0 between modal and creaky voicing for male and female speakers. Standard deviations are shown in parentheses.

As illustrated by Table 3, the average creaky F0 for women is 119.64 Hz, while the average creaky F0 for men is 85.26 Hz. I found that the average F0 for creaky voice was significantly higher for women than for men ($t(8) = 5.14$, $p = 0.001$). Unlike the results of Hollien and Michel (1968), my finding suggests that creaky voice produced by men has a different average F0 than creaky voice produced by women.

4. Discussion

My results suggest that women produce creaky voice more frequently overall than men, although the implementation of creaky voice within the syllable does not differ across genders. These results suggest that Yuasa's (2010) observations of Californian American English extend and apply to Midland American English and that creaky voice may be a sociophonetic marker amongst women in the United States more generally. This result contrasts with the results obtained by Henton and Bladon (1988), who found that creaky voice was a characteristic of the speech of men in the UK. The differences across studies may be explained by several factors. First, Henton and Bladon's (1988) study focused on two dialects of British English, while mine and Yuasa's (2010) examined dialects of American English. Thus, creaky voice may have different social meanings in the USA and the UK. Second, Henton and Bladon's (1988) study was conducted almost three decades ago. Although creaky voice had previously been associated with masculine speech, it is possible, as Yuasa (2010) hypothesized, that women have come to produce creaky voice in imitation of masculine speech as a way to assert themselves in a male-dominated society. Thus, a change in the social meaning of creaky voice may have occurred over the last three decades, so that creaky voice is now a social marker of female speech. In order to gain more support for this generalization, further research should compare the usage of creaky voice across genders in other regional dialects, such as Southern American English.

Unlike Wolk et al. (2012), I found that creaky voice is not a mode of speech exclusive to female speakers. In fact, I found only a modest difference in overall proportion of syllables containing creaky voicing for men and women, and the men and women in my sample used similar proportions of creaky voice within the syllables that they produced with creaky voicing (~90%). That is, while women were observed to use creaky voice more often overall, the

utterances containing creaky voice produced by the men did not differ in their implementation from those containing creaky voice that were produced by the women. Therefore, despite the modest difference in the overall amount of creaky voicing used by each gender, I suggest that the usage of creaky voice is similar within syllables across genders.

Finally, I found that the difference between the mean fundamental frequencies for modal voicing and creaky voicing is larger for women than for men by 53 Hz, consistent with my predictions based on the results of the study by Hollien and Michel (1968). However, unlike Hollien and Michel, I found that the average F0 for creaky voice was higher for women than for men in my study. In the female speech I examined, the average F0 during creaky voicing was 119.64 Hz; in contrast, in the male speech I examined, the average F0 during creaky voicing was 85.26 Hz. Because Hollien and Michel (1968) calculated the average ranges in F0 for each mode of voicing, rather than the mean F0 for each mode as I did, it is not possible to directly compare my results to theirs. However, their results showed average ranges of 24-52 Hz for male productions of creaky voice, and average ranges of 18-46 Hz for the female productions of creaky voice. For both genders, the average F0s for creaky voice that I found are higher than the upper limits of the ranges found by Hollien and Michel (1968). Thus, I am able to conclude that the average F0s for creaky voice for both genders are higher in my data than those found by Hollien and Michel (1968). This difference could be the result of changes in productions of creaky voicing over time, because several decades have passed since their experiment was conducted. I suspect, however, that the difference is largely due to the difference in the type of speech data that were used in each experiment. The data used by Hollien and Michel were productions of the vowel /ɑ/ that were produced with the intention of imitating pure tone stimuli. In contrast, my speech data are recordings of read paragraphs. Thus, the productions I examined

were potentially affected by other linguistic factors, such as prosody, which are not applicable to the data used by Hollien and Michel.

The difference in fundamental frequency between the two types of voicing for male and female speakers could provide an additional explanation for the relationship between the frequency of usage of creaky voice and gender. As noted above, Hillenbrand and Houde (1996) found that the most significant perceptual cue for creaky voice is the lowering of F0. The greater F0 difference between modes for the female speakers than the male speakers may contribute to greater perceptual salience of creaky voice in the productions of women than men. This greater salience may allow women to use creaky voice to convey social meanings, such as those proposed by Yuasa (2010), more easily than men, leading to the change in social meaning from a masculine (Henton & Bladon, 1988) to a feminine (Yuasa, 2010) characteristic.

The speech data used in this study were recordings of speakers reading the same set of passages to constrain the segmental and prosodic context in which I explored creaky voice. However, prosody is variable even in read speech (Clopper & Smiljanic, 2011). Because prosody is also a documented predictive factor for the use of creaky voice (Dilley *et al*., 1996; Redi & Shattuck-Hufnagel, 2001), the next stage of this research will involve considerations of prosodic structure in the realization of creaky voice across genders. Given that creaky voicing has been linked to particular prosodic environments, such as pitch-accented vowels (Dilley *et al*., 1996; Redi & Shattuck-Hufnagel, 2001), it is possible that there are more prosodic environments in which women tend to use creaky voice than men, lending some additional explanation for why creaky voice is observed more in the speech of women than men overall. Further studies should examine the combined effects of creaky voicing and prosody in the speech of men and women to explore this possibility.

Acknowledgements

I would like to thank my advisor, Cynthia Clopper, for all of the support and advice she has offered me for this project as well as my other academic endeavors over the years. I owe my entire undergraduate research experience to her, and I am very grateful for it!

Thanks are also due to Erin Luthern and Christine Prechtel, who have empathized, advised, encouraged, and otherwise provided moral support from start to end.

This work was partially supported by an Undergraduate Research Scholarship and the National Science Foundation (BCS-1056409).

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Appendix

Text of Read Passages

Passage 1: Booth

In my first week of college, there was a booth near my dorm that was meant to help lost students. You could ask the people inside for directions, and they were generally very helpful. Once the second week started, though, it was gone. I went to ask my friends and other students, and no one knew where it had gone. We spoke to the university administration, and they denied knowing anything about it. Over time, myths and rumors began to spread about the mysterious booth of unknown origin. One theory was that they had been told to stop after they had been giving directions that weren't completely true, or even blatantly false. They were the cause of a record number of students getting lost that year, the theory said. Another idea is that they never did stop but continued to give directions on different parts of the campus each day, moving quickly like nomads. There have even been unconfirmed sightings in the most unlikely of places, and this fact is the cause of endless speculation. A third theory is that it was actually a front for moving drugs around on campus. At the end of the day, I like the fact that no one knows what is invented and what is true, since the real reason it disappeared is likely to be quite uninteresting.

Passage 2: Faun

A faun is a mythological being, a nude half-man half-deer that lives deep in the forests. Free from greed, their only earthly possession is a pan flute, which is said to have magical properties. Their eloquent speech has been said to bewitch many travelers, encouraging them to strip nude and bathe in a nearby stream. Later, they will all dance under the full moon to the unearthly

melodies of the flute. After lying down to sleep on a bed of moss, the revelers will awake the next morning unsure if their memories are real. Of course, all of the forest creatures know that it is not the speech of the faun that is magical, but the stream. Imbued with the power of the spirits of the moon, its waters offer rejuvenation and youthfulness. It is these powers that make the bed of moss so soft and cushioned, and has driven many men mad with desire and greed. Most travelers don't realize that they are bathing in the secret to eternal youth.

Passage 3: Nigeria

After a long bus ride, David arrived in the town of Kankara, Nigeria, in the mid-afternoon. He had been able to snooze on the bus and felt ready for his adventure. The moment he stepped off the air-conditioned bus, however, he began to feel the sweat dripping off him, and seconds later he slapped the first gnats from his arm. Feeling twenty pounds heavier with the sweat soaking his clothes, he trudged down the road with a duffel bag in one hand and the other hand free to swat the bugs from his face. Arriving at his destination and meeting his hosts for the evening, he was amazed to see that not one person looked remotely uncomfortable in the heat or slapped at the gnats. After a pleasant evening of music and storytelling, he retired to his room to sleep. He spent nearly half an hour untangling the mesh of his mosquito net from his bag and setting it up above his cot. Next he tried unsuccessfully to snooze on the hard cot, but the buzzing of the mosquitos kept making him reach out and swat the mesh in his sleep, waking him up. Finally, resigned to sleeplessness, David realized that his adventure had just begun.

Passage 4: Ornament

My mother-in-law had a horrid-looking glass dog ornament, which for some unknown reason was on prominent display in the dining room. One day, I clumsily brushed against it and caused it to drop to the floor and shatter into many tiny pieces. Although I was expecting anger, my mother-in-law was just sad, and I was consumed with guilt – especially as she'd never really liked me much to begin with! I searched high and low, and eventually came across a glass dog in an antiques shop in Pittsburgh. Looking it over, and being careful not to drop it, I concluded that it was a perfect match. I told the owner of the shop that I didn't care about the cost, I needed this hideous creature. It wasn't cheap, but I bought it and took it to its new owner. You'd think that after I bought a replacement ornament at great cost, my mother-in-law would have liked me a little more or at least been a little less sad, but no! She simply remarked, forlornly, that it wasn't a perfect match but she supposed it was "close enough".

Passage 5: Pirate

Let me tell you the story of the ghost pirate Fernando, scourge of the seas. Fernando was once a young sailor aboard a merchant vessel in the late 1500s, sailing from Spain to the Caribbean. One hot day in July, he was ordered to swab the upper deck in the blistering sun. He had not slept at all that night – ghosts were said to haunt the ship, and there had been strange noises for the last week. The rest of the crew were scared, exhausted, and uncooperative. Fernando refused to swab the deck, as it was too hot outside and he was too tired. The captain went into a rage, and, citing the law of the sea, threatened to maroon Fernando on a desert island with only an axe and the Bible. None of the crew spoke up in defense of Fernando, for they feared the law of the captain more than the alleged ghosts, and Fernando was left on a tiny island. With only crab and

coconuts to eat, Fernando welcomed the change from the weevil-infested biscuits he'd had on the ship. Soon, though, the crab supply ran out, and water became scarce. His axe was no use for fishing. Dying of starvation, Fernando cursed the captain, and vowed to return to the ship as a ghost to haunt him and the crew for their coldheartedness.